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Impact of Non-Gaussian Statistics of Atmospheric Variables on Extreme Intramonth Anomalies

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Abstract—The analysis of asymmetry of probability distribution functions (PDF) is carried out for key atmospheric variables using the JRA-55 reanalysis data in the troposphere of the Northern Hemisphere for 1976–2014. The nonzero asymmetry of the PDF indicates the deviation of the PDF from the normal distribution. The analysis was carried out for two time-scale intervals: synoptic variability (SV) of 2–7 days and low-frequency variability (LV) of 9–30 days. Statistically significant deviations from the normal probability distribution occur in the regions of the most frequent formation of atmospheric baroclinic perturbations, i.e., over the western parts of the oceans in midlatitudes and downstream in the atmosphere. In the SV time-scale interval, a negative asymmetry of the vertical velocity is revealed in isobaric coordinates for the entire thickness of the free troposphere, which agrees with the overall dominance of cyclonic anomalies in this interval of time scales. In the LV interval, the asymmetry of this variable in the entire free troposphere is positive, which indicates the dominance of anticyclonic anomalies at these time scales. For the zonal velocity, temperature, and geopotential, the asymmetry sign of the PDF for variability with time scales of 2–7 days is different for the upper and lower free troposphere. The asymmetry of the PDF for atmospheric variables indicates the important role of the intermode interaction in the formation of baroclinic perturbations. The corresponding deviations of synoptic variability from the normal distribution, which is found in the upper troposphere of the subpolar and polar latitudes, can be related to the interaction of these perturbations with the winter polar vortex. These deviations of PDF from the normal distribution substantially increase the probability of the appearance of large (in absolute value) anomalies as compared to the case of the Gaussian PDF.

Keywords: atmospheric variations, atmospheric vortices, probability distribution function
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1. INTRODUCTION

Atmospheric variability is associated with the manifestation of baroclinic instability and eddy activity in the atmosphere. The details of different models of baroclinic instability differ markedly between each other. It is assumed in the classical Charney–Eady model [1, 2] (see also [3]) that the overall spatial structure of atmospheric disturbances is determined by the corresponding structure of the most unstable baroclinic wave. The problem of the development of these perturbations becomes linear and does not take the interaction between different baroclinic waves into account. Such an interaction, as a rule, is nonlinear [4] and can be important during the greater part of the life of baroclinic atmospheric vortices [5].

A comprehensive analysis of variations in the atmosphere, which are considered a climate-forming process, involves the analysis of probability distribution functions (PDF) of atmospheric variables [6–8]. In particular, such an analysis allows us to draw conclusions about the contribution of nonlinear interactions to the development of baroclinic perturbations [9]. In the linear approximation for atmospheric dynamics, we can expect normal sample PDFs of the main variables. Nonlinear interactions, in turn, can lead to non-Gaussian PDFs.

Traditionally, atmospheric (meteorological) variability is divided into components that correspond to different intervals of temporal and spatial scales [10, 11]: high-frequency, with a period <2 days and a zonal